**Reservoirs, processes and residence time**

Objective:

Students will be able to accurately predict how a system can be characterized by reservoirs, processes and residence time and how a system will change when the reservoir size and/or processes change.

Students should study the USGS website on the hydrologic cycle ( http:// ) before attempting to complete this exercise

Reservoirs: Several connected containers of water can serve as a model for the more complex natural water cycle.

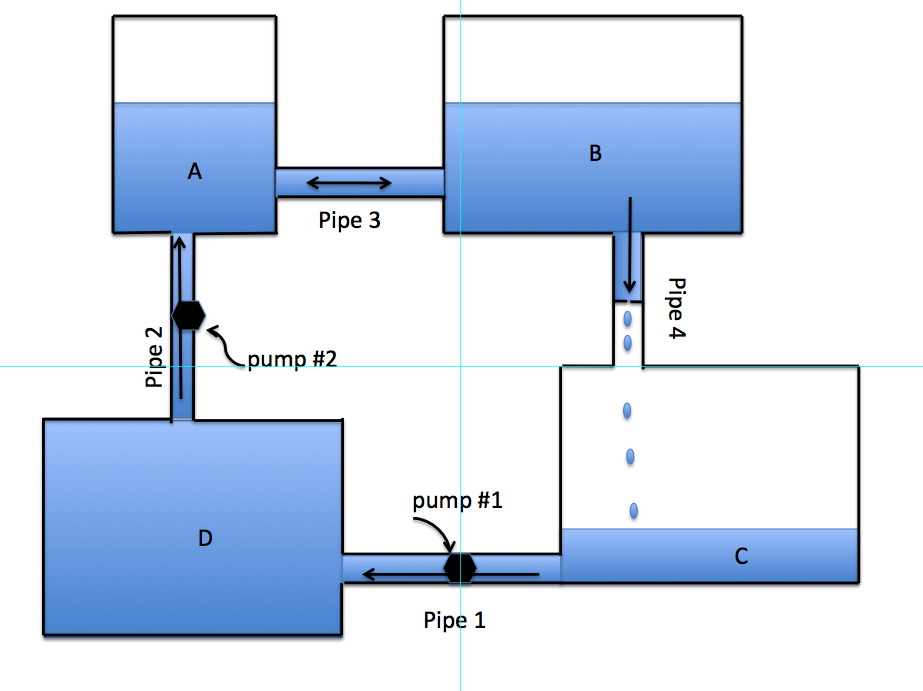


Figure 1. A simple sytem with water in 4 connected containers.

Figure 1 depicts four containers of water with water flowing between them. Arrows show the direction of flow. The double arrow between containers A & B shows that water can flow either way through the connecting pipe #3. Water from container B drips into container C through a small hole in a restriction across the pipe. Water is forced from containers C and D by pumps #1 and #2. Assume that the pumps are electric and connected to an electric outlet by wires.

**Part 1 Reservoirs and processes**

**A. Alignment and inference**

There are aspects of the simple system shown in Figure 1 that are similar to aspects of the water cycle. For each aspect of the simple system (Figure 1) listed in table 1, list a similar aspect from the water system. Note that for each aspect of the simple system there is more than one similar aspect of the water cycle. Therefore, there is more than one way to correctly complete table 1. There are also relationships between aspects that are similar. In the right-hand column of figure 1, describe the relationship. Some parts of table 1 have been filled in to provide and example. In this example, we are considering the containers in Figure 1 to be to be reservoirs and the pipes with whatever is within the pipes to represent processes that move and/or change water

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|  |  |  |
| --- | --- | --- |
| **Simple system** | **Water cycle** | **Relationship** |
| Container A | *Water vapor in atmosphere* | *Both are reservoirs* |
| Container B | *Liquid water in clouds* | *Both are reservoirs* |
| Container C | *Liquid water on ground surface* | *Both are reservoirs* |
| Container D | *Liquid water in lake* | *Both are reservoirs* |
| Pipe 1 | *Surface runoff* | *Energy in the form of gravity( water cycle) or electricty (pump 1) moves water from one reservoir to another.* |
| Pipe 2 | *Evaporation* | *Energy in the form of solar radiation) or electricty (pump 1) moves water from one reservoir to another.* |
| Pipe 3 | Condesnation/evaporation | *Pipe 3 allows flow back and forth between reservoirs A& B. Condensation and evaporation moves water back and forth between between clouds and the atmosphere.* |
| Pipe 4 | precipitation | *Gravity causes water to flow from reservoir B to C and from clouds to Earth’s surface.* |

Table 1

We may use inferences about simple systems to make inferences about more complex systems. What would happen to the simple system if you made the hole in the restriction in pipe 4 larger?

*Reservoir B would decrease in size and reservoir C would increase in size.*

Based on what you wrote in table 1, what is the analogous change that would happen in the water cycle if you made the hole in pipe 4 larger?

*If the rate of global precipitation were to increase, cloud cover would decrease.*

Figure 2 shows another simple system but with 6 containers rather than 4. Like figure 1, figure 2 may be a simple model of the water cycle.



Figure 2.

Fill in table 2 as in the same way you filled in table 1 but with container A now analogous to groundwater.

|  |  |  |
| --- | --- | --- |
| **Simple system** | **Water cycle** | **Relationship** |
| Container A | *goundwater* | *Both are reservoirs* |
| Container B | *stream* | *Both are reservoirs* |
| Container C | lake | *Both are reservoirs* |
| Container D | atmosphere | *Both are reservoirs* |
| Container E | cloud | *Both are reservoirs* |
| Container F | ground surface | *Both are reservoirs* |
| Pipe 1 | precipitation | *Gravity (precipitation) or electricity (pump1) moves water from one reservoir to another.* |
| Pipe 2 | recharge | *Gravity (recharge) or electricity (pump 2) moves water from one reservoir to another.* |
| Pipe 3 | discharge/recharge | *Gravity moves water back and forth from one reservoir to the other.* |
| Pipe 4 | *discharge/recharge* | *Gravity moves water from one reservoir to the other.* |
| Pipe 5 | evaporation | *Gravity moves water from reservoir B to C whle evaporation driven by solar energy moves water from a lake to the atmosphere.* |
| Pipe 6 | condensation | *Gravity moves water from reservoir D to e while thermal/chemical energy drives condensation* |

Table 2

**B: Abstraction & Redescription of the domains**

When components of two domains are analogous a common principle can be used to describe both. For every corresponding pair of components in table 3, use a single word or phrase that can be used to describe the common relation, role or principle. One common principle has been filled in to serve as an example.

|  |  |  |
| --- | --- | --- |
| **Simple system** | **Water cycle** | **Common principle** |
| Water in containers | Water in reservoirs | *Water resides in definable states and locations.* |
| Containers contain varying amounts of water. | Reservoirs have a range of sizes. | *The amount of water in a reservoir depends on the rates of inflow and outflow.* |
| Containers are connected. | Water moves and changes from one reservoir to another. | *A variety of processes move and/or change water from one reservoir to another.* |
| Water flows in one or two directions between containers. | Water my flow in one or two directions between reservoirs. | *There are a limited number of waters water can move and/or change.* |

Table 3.

**Part 2 Residence time**

Residence time is the average amount of time that a material remains in a reservoir. Residence time is calcualted by the following equation:

R.T. = amount in a resevoir ÷ flow in ( or out) of the reservoir.

In this section of the exercise, we will compare the residence time of water in the containers in the simple system with the residence time of water in the water cycle..

Alignment:

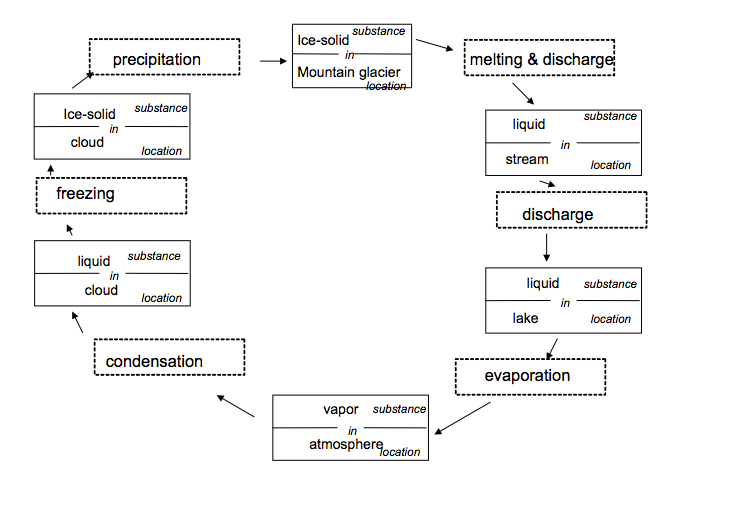
Complete table 4 by listing changes in the water cycle that are similar to changes in the simple system shown in figure 2. In the right-hand column, write increase, decrease or no change in the residence time based on you wrote in the middle column.

|  |  |  |
| --- | --- | --- |
| **Simple system** | **Water cycle** | **Affect on residence time** |
| Remove some of the water in container A from the whole system. | *Remove some water from groundwater* | *Decrease residence time of groundwater* |
| Decrease the rate of pumping (pump #1). | *Decrease precipitation rate* | *Increase residence time of water in clouds* |
| Increase the hole size in pipe #4 | *Increase discharge from stream to lake* | *Decrease residence time of water in lake.* |
| Increase the amount of water in reservoir C | *Increase amount of water in lake* | *Increase residnece time of water in lake* |

Table 4

Assessment:

1. Complete the box and arrow diagram below



2. How, if at all, global warming will change the residence time of water in the oceans? Explain your answer.

*It will increase the residence time because glacial ice will melt and most of the water will be in the oceans, increasing the size of the reservoir. If fluxes in and out of the oceans remain unchanged, then residence time will increase due to the increase size of the reservoir.*